Sloan Digital Sky Survey and Hubble Ultra Deep Field Data Imply a New Cosmological Model

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New empirical data from over 756,000 galaxies in the Sloan Digital Sky Survey and corroborating data in the literature from 1308 galaxies in the Hubble Ultra Deep Field are inconsistent with basic Big Bang theory predictions. These robust high-quality datasets instead confirm the predictions of a simpler cosmological model having no free parameters to adjust the model's predictions of empirical observables. This new model predicts high-quality empirical observations with unprecedented precision, rests on established first principles and does not interpret astrophysical observables as accelerating cosmic expansion. It is primarily based on a synthesis of Riemannian geometry and insights concerning the geometric nature of relativistic time arising from fundamental contributions to the relativity theory made by Einstein's university mathematics professor, Hermann Minkowski (1864–1909).

In the late 20th century, measurements were being conducted to determine the value of the expected cosmic deceleration parameter (q). Deceleration was expected because gravity is an exclusively attractive force: it was believed that mutual gravitational attraction of all galaxies should cause the expansion of the Universe precipitated by the Big Bang to gradually and increasingly slow down over time, similar to the slowing of any mass ejected vertically from the Earth's surface. In 1998 it was announced that, instead of the expected deceleration, astronomical observations implied the existence of an accelerating cosmic expansion (*1,2*). Because this notion is inconsistent with the foundations of physics, a scientific crisis ensued and the ill-defined term 'dark energy' was coined to give a name to the unknown agent causing the apparent acceleration of cosmic expansion. Robust new empirical evidence implies inaccuracies in previously reported empirical data that led to the cosmic acceleration interpretation and the ensuing scientific crisis. This new data, additional astrophysical data and a new theory accurately predicting cosmological observables, which are discussed at length in a comprehensive dissertation in progress, for which a preview edition is currently available, also imply an unexpected and unprecedented complete revision of the standard cosmological model (*3*). Readers without expert background in modern cosmology are encouraged to read a brief supplementary background review, which is available online (*4*), prior to proceeding with the following main article.

2dF observations support the Big Bang theory. The Two Degree Field (2dF) Galaxy Redshift Survey of about 250,000 galaxies in the southern sky (*5*), which was a British-Australian effort completed in 2003, represented the largest available cosmological dataset until more recent progress of the American Sloan Digital Sky Survey (SDSS), which has mapped and analyzed over one million galaxies and quasars in the northern sky (*6*). The tiny blue dots in Fig. 1 are reported measurements of the redshift and

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apparent magnitude in violet to green visible light (m_{Bj}) for 220,661 individual galaxies identified as having accurate high-quality measurements. The dataset is so large that most of the dots appear as a solid blue mass in the graph. Given the apparent assumption that the brightest galaxies (the base of the dataset) represent a standard candle, the 2dF data shown in Fig. 1 provides strong confirmation of the 'Hubble law' underlying the standard cosmological model, yet relativistic time dilation dimming (*7*) is noticeably absent.

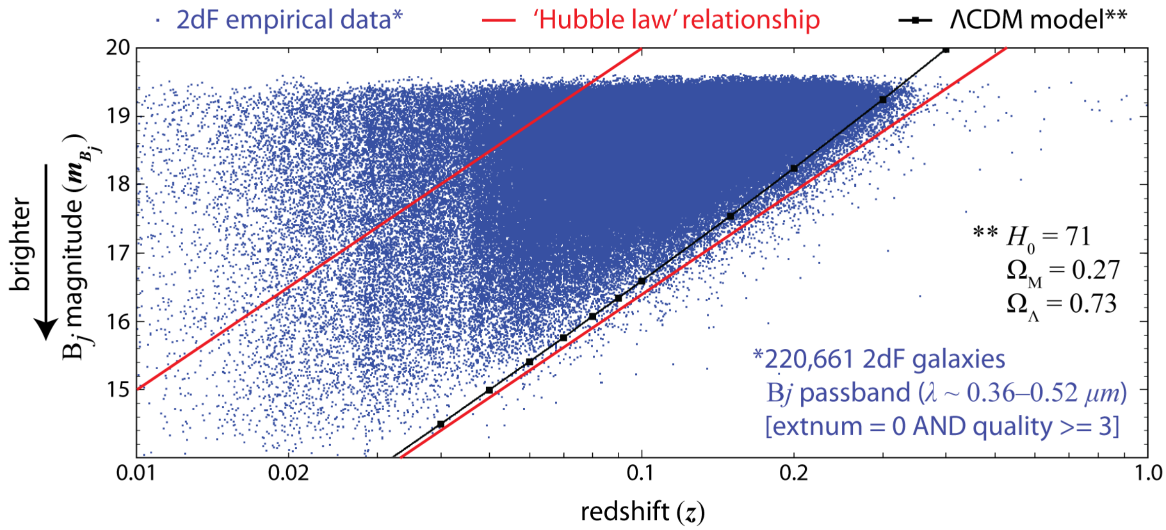

Fig. 1. The redshift-magnitude diagram from the 2dF galaxy redshift survey database. This graph's boundaries truncate 5.4% of the complete 2dF database population of 233,251 galaxies for the selection clause (extnum = 0 and quality ≥ 3), which returns data with high-quality redshift measurements. The survey employed a B*j* bandpass filter, which primarily includes blue light, although this wide band ($0.36 < \lambda < 0.52$ μm) extends from violet to green. The plotted coordinates are the *z_helio* and *BJSEL* columns of the online 2dF database. The parallel red lines show an increase of exactly five magnitudes (÷100) in apparent luminosity for a ten-fold increase in redshift. Strangely, this data is a better fit to a naïvely simplistic relationship accounting only for the inverse square law than a more sophisticated model (black Concordance model curve) that of necessity accounts for relativistic effects (*8*). Empirically, dimming of a standard candle due to distance is accompanied by relativistic time dilation dimming: at $z = 0.04$, time dilation dims a standard candle by 0.09 *mag* and at $z = 0.4$, by 0.73 *mag*, thus a standard candle cannot possibly follow a strict 'Hubble law' redshift-magnitude relationship empirically.

SDSS observations refute the Big Bang theory. The Sloan Digital Sky Survey (SDSS) has been the most ambitious and complete galaxy redshift survey to date. The tiny red dots in Fig. 2 are reported measurements of the redshift and SDSS *i′*-band apparent magnitude (m_i) for 756,851 individual galaxies identified as having accurate high-quality measurements per limited values [3, 4, 6, 7, 9] of the SpecObj.zStatus SDSS SkyServer database column (*9*). The *i′*-band "fiber magnitude" specifying the measured brightness of galaxies is the flux contained within the aperture of a spectroscopic fiber with a diameter of three arcseconds on the sky (*10*). Quasars are excluded, so the plotted galaxies are all of the same spectral class. The survey is magnitude limited; galaxies

brighter than m_i = 14.5 were excluded from measurements to prevent saturation and cross-talk in the spectrographs (*11*). The average error in the magnitude measurement is less than 0.01 *mag*, which is smaller than the dot size on the graph. The typical error in the redshift measurement is similarly small on the redshift scale of the graph. This dataset was acquired without a theoretical agenda; instead, the practical agenda was to ensure individual measurement quality, yielding a collective "cosmic map" providing an unadulterated factual cosmological perspective.

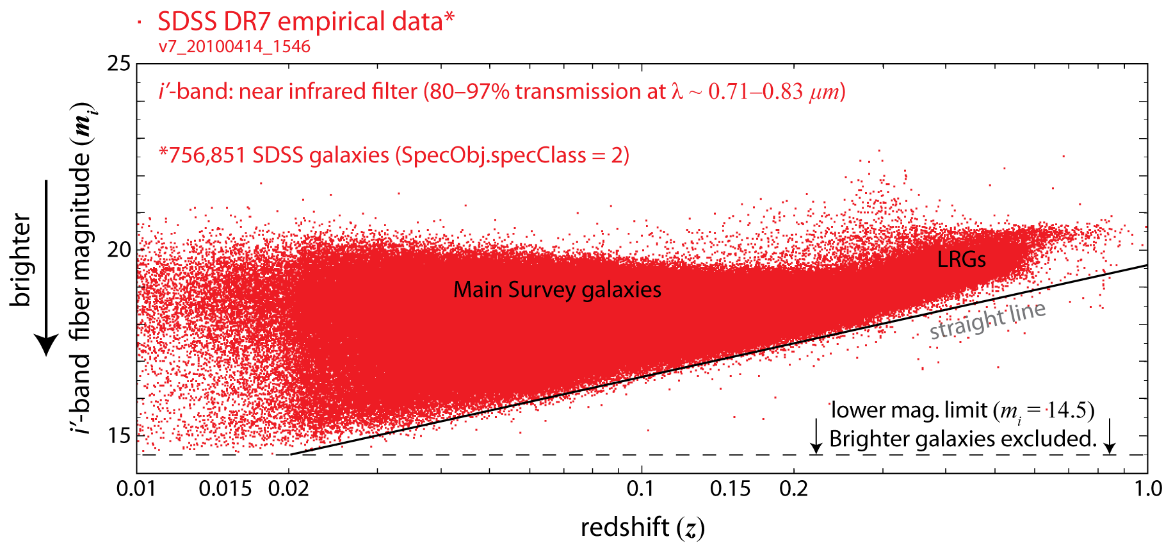

Fig. 2. Over 756k high-quality SDSS *i'*-band redshift-magnitude measurements restricted to the galaxy spectral class appear in red. The solid black straight line is approximately tangent to the base of the dataset. With the relatively rare exception of unusually bright outliers, galaxies brighter than the neighborhood of this line do not exist. Like the 2dF dataset, the base of this dataset represents the *brightest galaxy* class, assumed to represent a standard candle because it is not sensible for a large systematic change in their absolute luminosity to exist as a function of redshift. However, the slope of the base of the SDSS dataset is unexpectedly very different from that of the 2dF dataset, which requires explanation. Additionally, a definite increase in the slope of the base of the SDSS dataset is seen for ($z > 0.2$), which is qualitatively similar to that seen in SNe Ia redshift-magnitude data. The faint galaxy (top surface of the dataset) population surge at high-redshift is an artifact of the Luminous Red Galaxy (LRG) Survey (*12*), which is incorporated with the Main Survey.

The SDSS data shown is most remarkable in that it does not support the 'Hubble law,' which is made plainly evident in Fig. 3. The solid curve in blue represents the standard cosmological model (*8*). The increase of 5.3 *mag* between ($0.02 \leq z \leq 0.2$) is a reflection of the 'Hubble law' and the luminosity inverse square law. At what is modeled to be a factor of ten increase in distance (D) for the same in redshift, the modeled apparent luminosity ($L \propto D^{-2}$) has decreased by a factor of 100, with the excess 0.3 *mag* attributed primarily to relativistic time dilation dimming [$(z + 1)^{-2}$]. Large-scale cosmic geometry (i.e., "spacetime curvature") causes an additional decrease in the apparent luminosity of galaxies at cosmological distance. Although the solid blue curve in Fig. 3 represents the

Concordance cosmology, variation of assumed free parameters such as *lambda*, which is related to the alleged acceleration, cannot alter the fit of the curve to the 'Hubble law,' particularly over this redshift range. The dashed blue curve shifts the solid line down about 3.1 magnitudes (×17.4) at z = 1, correlating the prediction with the high-redshift empirical data at z = 0.6, rather than the low-redshift z = 0.02 data. If the 'Hubble law' holds, no galaxies should exist that appear brighter than (i.e., below) the solid blue line, but hundreds of thousands do; alternatively, there is an empirical deficit of galaxies (blank area) that appear fainter than (i.e., above) the dashed blue line.

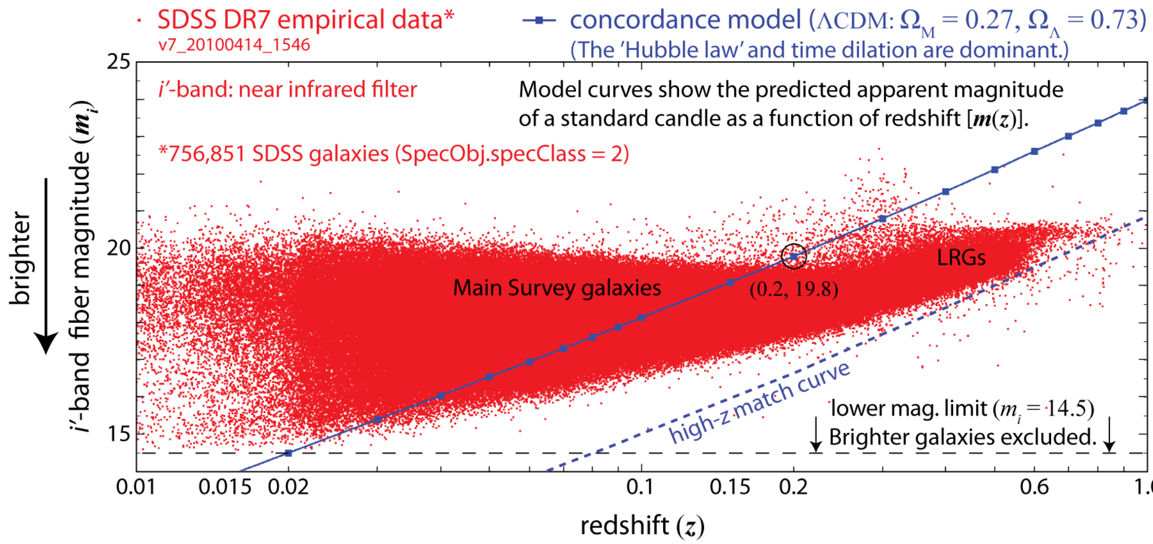

Fig. 3. SDSS i'-band data compared to ΛCDM Concordance model curves. Given the understanding that the base of the $z > 0.02$ dataset represents a standard candle, the empirical data does not support the 'Hubble law.' The existence of vast numbers of galaxies below the solid blue curve implies that this curve is not an accurate redshift-magnitude model. The dashed curve in blue shifts the solid curve down 3.1 *mag* at $z = 1$ to match the high-redshift empirical data. The massive deficit of galaxies (blank area) between the dashed blue curve and the empirical data ($z < 0.6$, $m_i > 14.5$) implies that this "high-z match curve" is not an accurate redshift-magnitude model.

Because the Hubble law provides the foundation of the standard cosmological model, one might assume that the SDSS team unknowingly incorporated a huge systematic error in their measurements of galaxy luminosity. Error bars in the magnitude measurements are on the order of 0.01 *mag*, but deviation between theory and empirical data in Fig. 3 grows to ~3 *mag*. or ~300× the reported measurement error. It is difficult to believe that such an enormous systematic error could exist, let alone go unnoticed by every member of a large world-class team of scientists and technicians. An alternative possibility is that the SDSS redshift-magnitude data is empirically accurate but was never presented for critical analysis as shown in Fig. 3. Thus, the scientific implication of this data that was 'hiding' in the database was simply overlooked. Trusting that the empirical data produced by the SDSS consortium is accurate as claimed puts the standard cosmological model and the general theory of relativity upon which that model is based in jeopardy.

The geometry of time in relativity and cosmology. In 1908, Hermann Minkowski provided a formal mathematical foundation for the special theory of relativity. In addition to unifying space and time, Minkowski had geometrized time, yet Albert Einstein, who initially dismissed this mathematics as "superfluous erudition" (*13*), subsequently never developed an adequate understanding of Minkowski's critical contribution to relativity. Minkowski died suddenly in January 1909 at the age of 44, so his work in progress was never finished. Because Einstein, his contemporaries and several following generations of theoretical physicists never properly understood *the geometry of time* implied by Minkowski, general relativity and the standard cosmological model, which is based on this theory, were both flawed and remained uncorrected in the twentieth century.

The following parsimonious mathematical equation predicts the apparent magnitude of a cosmological standard candle as a function of redshift. It is based on the idea that the relativistic cosmological *geometry of time* implied by the principles of relativity results in a redshift-distance relationship that is independent of any relative motion. This equation, expressed in the simplest form of Pogson's equation (*14*), which defines the astronomical magnitude scale, rests on pure Riemannian geometry and on fundamental laws of physics that have been empirically verified in the laboratory. It has no free parameters that may allow the prediction to be manipulated *a posteriori* to improve its fit to observations.

$$m(z) = C - 2.512\log\left(\frac{1}{4\pi\left[(z+1)^4 - (z+1)^2\right]}\right) \qquad [z > 0] \tag{1}$$

The "MdR" cosmological model, which spawned this equation, is based on a synthesis of original ideas put forward by Hermann **M**inkowski (1864–1909), Willem **d**e Sitter (1872–1934) and Bernhard **R**iemann (1826–1866). The fractional term in Eq. 1, which represents a normalized luminosity, incorporates a product of three distinct terms:

(**a**) a geometric term associated with a spatially finite yet boundaryless symmetric spacetime (i.e., a Riemannian hypersphere with a finite volumetric 'surface area' whose local vertical represents the strictly local cosmologically relativistic time coordinate);

$$\frac{1}{4\pi\left(1 - \frac{1}{(z+1)^2}\right)} \qquad [z > 0] \tag{2}$$

(**b**) the familiar term in astrophysics associated with relativistic time dilation dimming of a radiation source: $(z + 1)^{-2}$;

(**c**) a second relativistic term associated with the effect of cosmic geometric symmetry enforced by gravity (i.e., "spacetime curvature") on the apparent luminosity of a standard candle with redshift. Previously unknown, the value of this term is also $(z + 1)^{-2}$.

The constant 2.512 is the fifth root of 100 (i.e., Pogson's ratio), which is the base of the astronomical magnitude scale. The arbitrary constant C is determined for a class of standard candle (e.g., brightest conventional galaxies) and bandpass filter (e.g., i'-band)

according to an observed reliable empirical relationship (z_0, m_0). This equation is among several similar *a priori* exact theoretical predictions of cosmological observables in the MdR theoretical model that rest exclusively on first principles and four-dimensional Riemannian geometry. There are no free parameters involved in any MdR prediction.

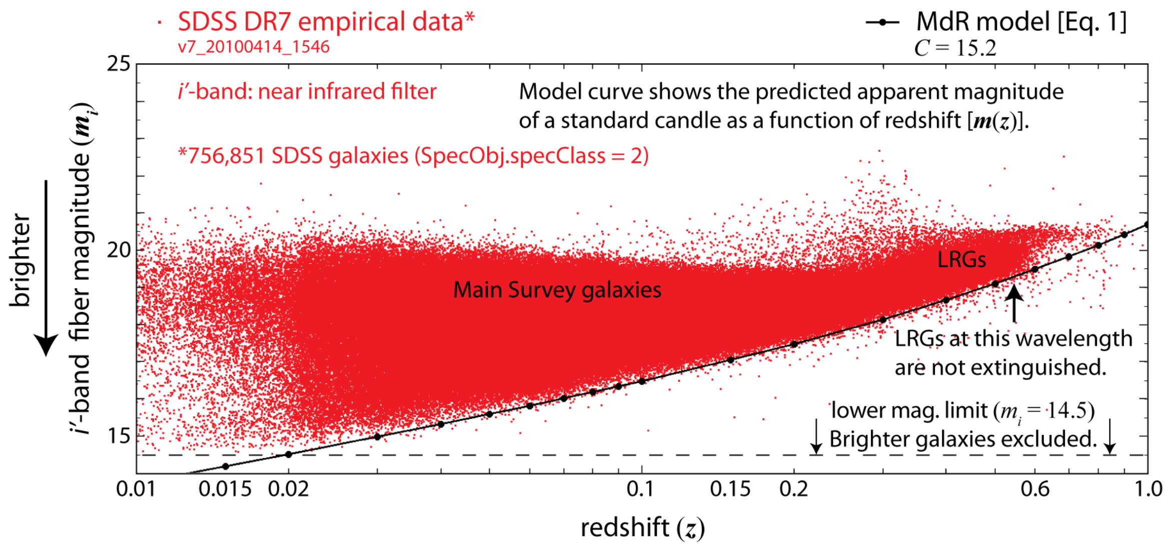

Fig. 4. SDSS *i*′-band data compared to MdR model curve. This MdR model assumes a standard candle in a perfect vacuum. In reality, an intergalactic medium (IGM dust) exists; longer wavelength (i.e., redshifted) infrared (IR) radiation penetrates this dust better than shorter wavelengths. Accounting for geometric and relativistic effects, a more distant redshifted standard candle viewed at longer IR wavelengths that better penetrate dust will appear to be brighter relative to a closer standard candle viewed at shorter IR wavelengths, which are "extinguished" (i.e., dimmed) by IGM dust. Accordingly, the small gap between the MdR curve and the empirical data at $z = 0.02$, which narrows over the redshift range ($0.02 \leq z \leq 0.6$), shows about 0.25 magnitude (~26%) relative brightening of the empirical data over this range. (If the gap were removed by shifting the model up ~0.25 *mag*, the high-redshift data would fall below the model curve indicating that the longer wavelength light is relatively brighter than the shorter wavelengths. This effect is more prominent in the *z*′-band (infrared) data shown in Fig. S2.

In Fig. 4, the empirical redshift-magnitude curve for brightest conventional galaxies (excluding outliers) is very accurately predicted by invoking only relativistic effects and cosmic geometric symmetry as modeled by Eq. 1 (solid black curve). This is additional evidence to Fig. 3 that the 'Hubble law' is indeed false. Eq. 1, which rests *a priori* on first principles and geometry, provides an essentially perfect fit to the SDSS empirical data; that this could be so without physical cause or meaning is implausible. Comparing the two competing models to the empirical data in Fig. 3 and Fig. 4, it is absolutely clear which model's predictive curve fits the empirical data and which model's predictive curve does not correlate with the data. Moreover, the SDSS data is so good that one can see the effect of the intergalactic medium, which scatters and extinguishes light with a wavelength apparently smaller than the average-sized IGM dust grains while allowing longer wavelength light to pass more freely (see Fig. 4 legend and Fig. 5).

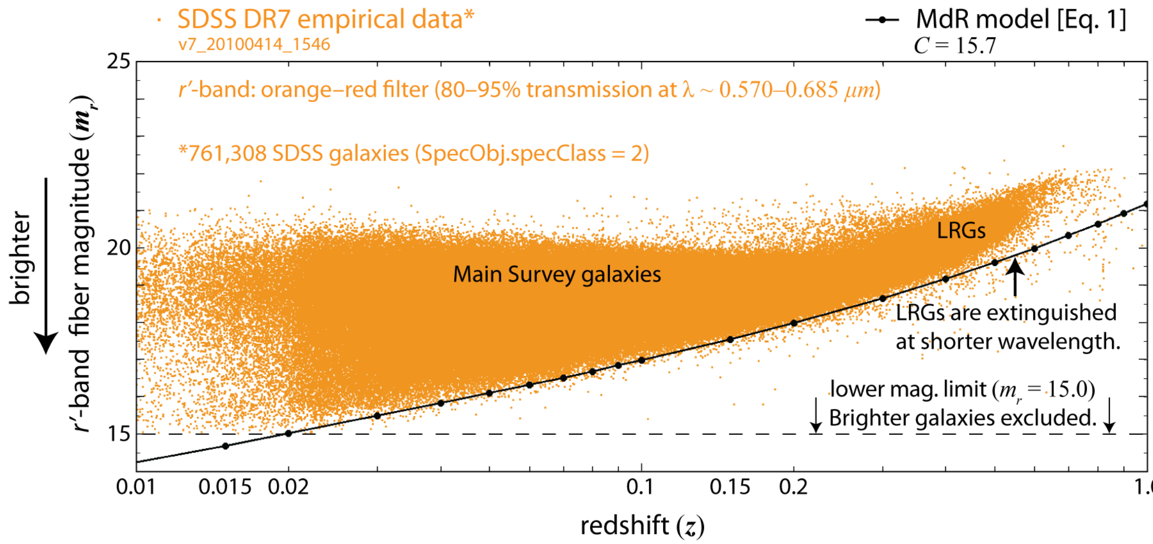

Fig. 5. SDSS *r′*-band (orange-red light) data compared to MdR model curve. This filter's light is too short to avoid scattering (i.e., "extinction") by dust. The observed dimming of the $z > 0.4$ *r′*-band data relative to the MdR model curve, which differs from the behavior seen in the *i′*-band data (no dimming) shows that the Luminous Red Galaxies (LRGs) are locally surrounded by dust, which blocks shorter wavelengths. This extinction effect is amplified for shorter wavelengths as seen for blue–green light in Fig. S3. Note that the arbitrary constant in Eq. 1 for the *r′*-band data curve requires an increase from its *i′*-band value by 0.5 *mag* to $C = 15.7$, matching the increase in the SDSS fiber magnitude cut at this shorter wavelength (horizontal dashed line).

However compelling the match of the SDSS empirical dataset to the Eq. 1 theoretical prediction, a skeptic may claim that since this dataset terminates well before $z = 1$, a demonstration of predictive accuracy at high redshift is required for a comprehensive vetting of the MdR model as concerns the empirical redshift-magnitude relationship. Thus we turn to the Hubble Ultra Deep Field (HUDF) image, which includes 1,308 conventional galaxies, many at very high redshift, whose fundamental properties have been measured from the data with good reported accuracy by R. E. Ryan *et al*., also using an *i′*-band filter (*15*). These measurements appear as the small red dots plotted in Fig. 6. The identical predictive curves seen in Fig. 3 and Fig. 4 for the SDSS *i′*-band data appear in this graph, although they have now been extended to a redshift of $z = 6$. This HUDF data provides accurate empirical measurements from the SDSS cutoff for typical galaxies ($z < 1$) to the farthest reaches of the observable universe with current technology ($z > 6$). Recall that a large portion of the SDSS *i′*-band data exists between the two curves shown in the Fig. 6 graph, but, with the rare exception of outliers, no galaxies exist empirically below the MdR curve. In Fig. 6, as in Fig. 3, there is no correlation between the standard model curve in blue and the HUDF empirical data, yet the MdR model curve in black is remarkably consistent with these high-redshift observations. Where there is similarly plentiful accurately measured astrophysical data, MdR model predictions match other empirical observables related to cosmology with similar precision as that exhibited for the SDSS and HUDF empirical redshift-magnitude curves (*3*).

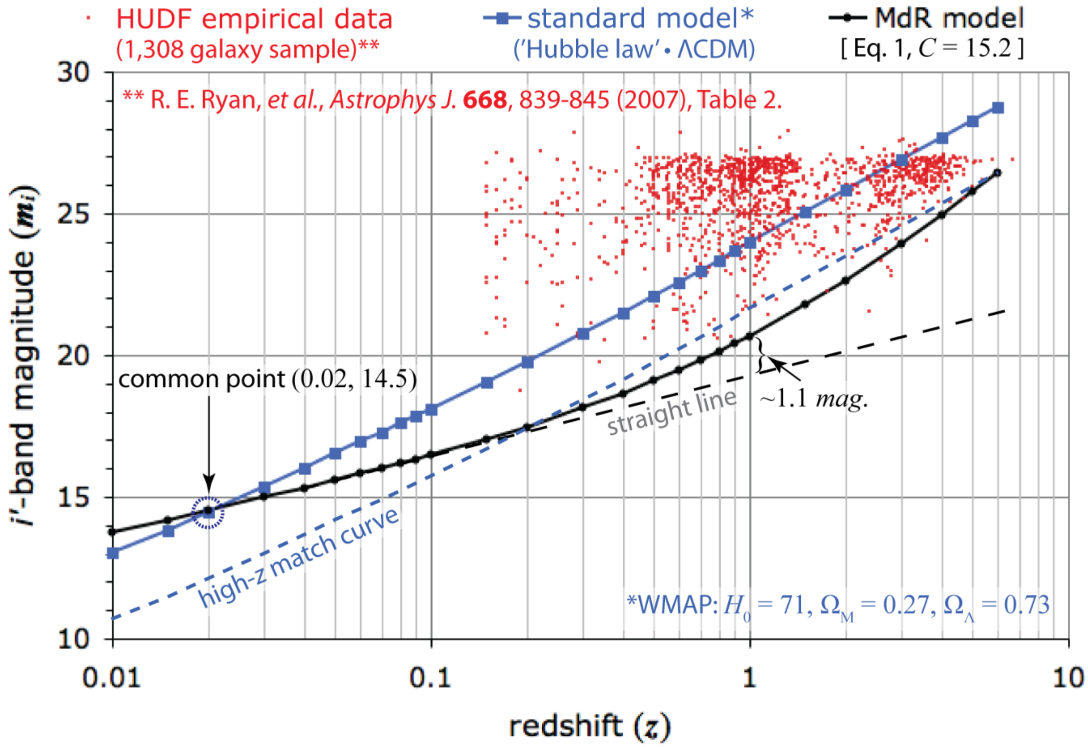

Fig. 6. HUDF empirical *i'*-band data in red compared to the same redshift-magnitude models shown in Fig. 3 and Fig. 4. The two solid curves shown here simply extend the former curves out to high redshift. The dashed curve in blue ("high-*z* match") shifts the solid curve down to match the high-redshift empirical data. If this curve were an accurate redshift-magnitude model, thousands of galaxies would exist filling the region between this dashed blue curve and the solid black MdR curve ($z < 0.2$). Empirically, as seen in the SDSS *i'*-band data in Fig. 4, no such galaxies exist. The fit of both the SDSS and the HUDF empirical datasets to the MdR predictive curve, which was not known when the datasets were produced, is indicative of the remarkable quality of the observational data. Note the highest redshift galaxy in the HUDF dataset; what must be an intrinsically very bright galaxy to be visible at this redshift (nearly $z = 7$) falls on the MdR predictive curve.

If the unbiased SDSS and HUDF measurements can show the demonstrated accuracy, then all previously published empirical redshift-magnitude curves and error bars, which supported the 'Hubble law' and the Big Bang paradigm by expectation, require retraction and correction. Given the scientific facts revealed in this article, if SNe Ia are reliable standard candles, the raw SNe Ia data should show the same redshift-magnitude curve defined by Eq. 1. In the effort to measure q, the important discovery of an increasing trend in the slope of the SNe Ia redshift-magnitude curve was correct, but the reported average slope for the supernovae is inconsistent with statistically and procedurally far more reliable empirical SDSS data. An accurately reported empirical redshift-magnitude curve changes the interpretation of the observed slope increase with redshift while dispensing with the dubious concept of 'dark energy' and overthrows the standard cosmological model (i.e., the Big Bang theory). It also dispenses with the notion that

distant galaxies are receding from the Milky Way Galaxy at speeds greatly exceeding the speed of light, which was one of several acts of handwaving needed to maintain the idea that the Universe is expanding. Although the cosmic microwave background (CMB) radiation and its more recently measured anisotropies have been touted as proof of the Big Bang theory, if the 'Hubble law' does not hold and therefore the Universe is not expanding, the CMB requires a new explanation to replace the conventional belief that it represents leftover heat from a primordial explosion assumed to have occurred about 13.7 billion years ago. This has been addressed in the referenced dissertation, including readily observable empirical predictions (*3*).

The MdR theory introduced herein is based on an amendment to the treatment of time in the theory of relativity. A number of important corrections to 20th-century theoretical physics arise from this amendment, in addition to those in the field of cosmology.

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12. SDSS, *Luminous Red Galaxies* (2007), (available at http://www.sdss.org/dr7/algorithms/target.html#lrg).
13. A. Pais, *Subtle is the Lord… The Science and the Life of Albert Einstein*, (Oxford University Press, Oxford, 1982), p. 152.
14. Pogson's equation may be written [$m = k - \sqrt[5]{100}\log_{10} B$] where B is apparent brightness and k is some constant. Given the approximation $\sqrt[5]{100} \approx 2.512$ (Pogson's ratio), then $2.512^{\Delta m}$ is the factor by which apparent brightness changes for change in magnitude of Δm.

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[data available at http://jaypritzker.org/J/1/Ryan (redirects to iop.org)]

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Supporting Online Material

Materials and Methods
Figs. S1, S2, S3

SEE http://jaypritzker.org/J/1/HowTo (be transferred to journal website)

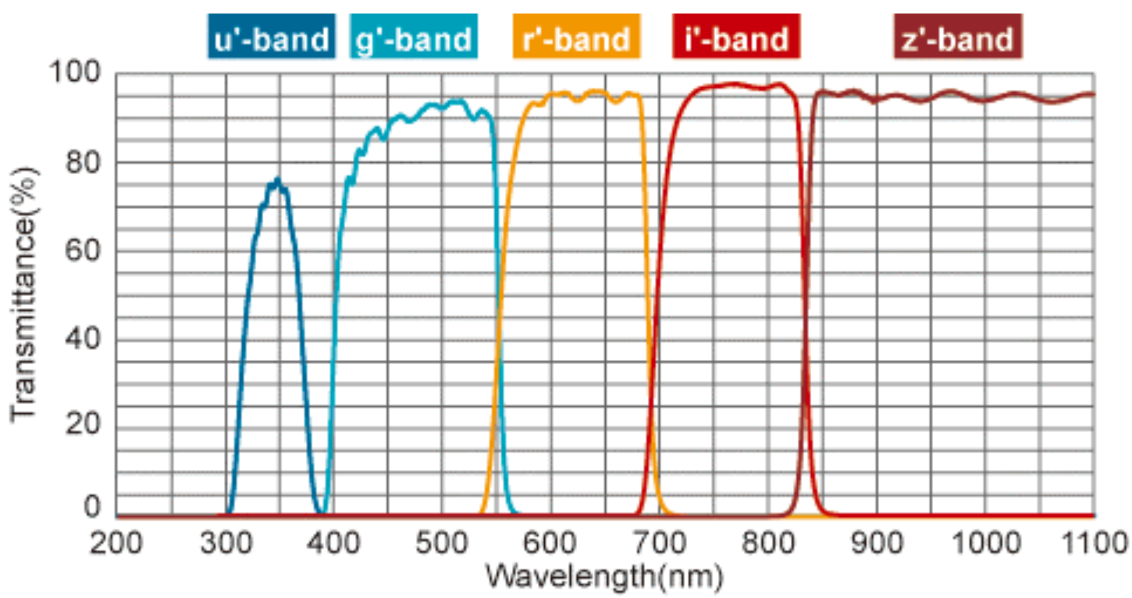

Fig. S1. SDSS bandpass filter characteristics (ASAHI Spectra USA).

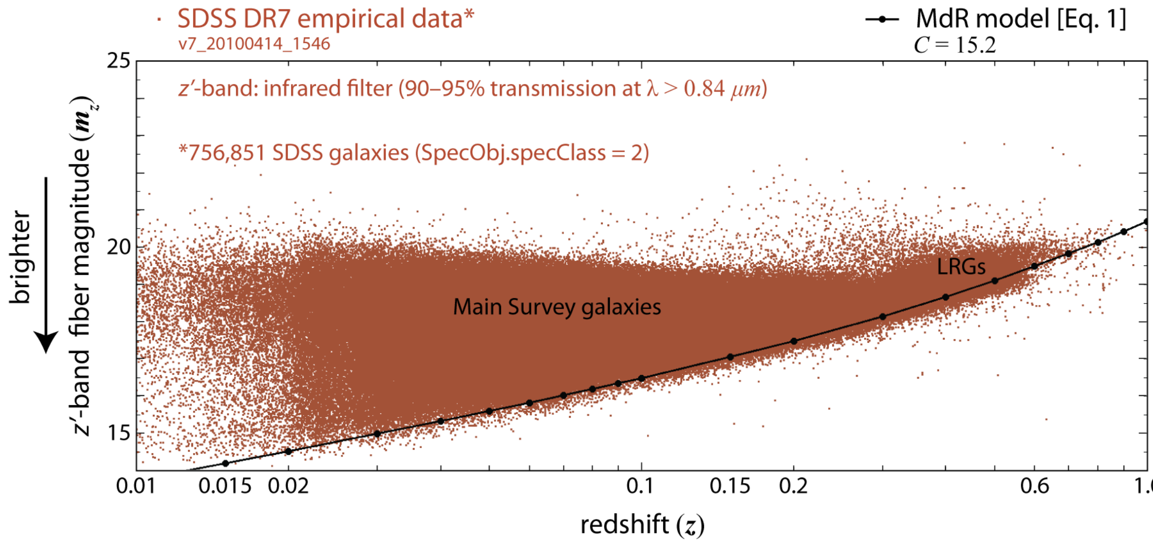

Fig. S2. SDSS z'-band (infrared) data compared to MdR model curve. The tendency of longer-wavelength IR photons to better penetrate the IGM dust is more pronounced for the g'-band data than for the i'-band data. Thus, the g'-band data is slightly brighter overall than the i'-band data and the relative brightening of the base of the dataset relative to the zero extinction MdR model with increasing redshift is slightly amplified.

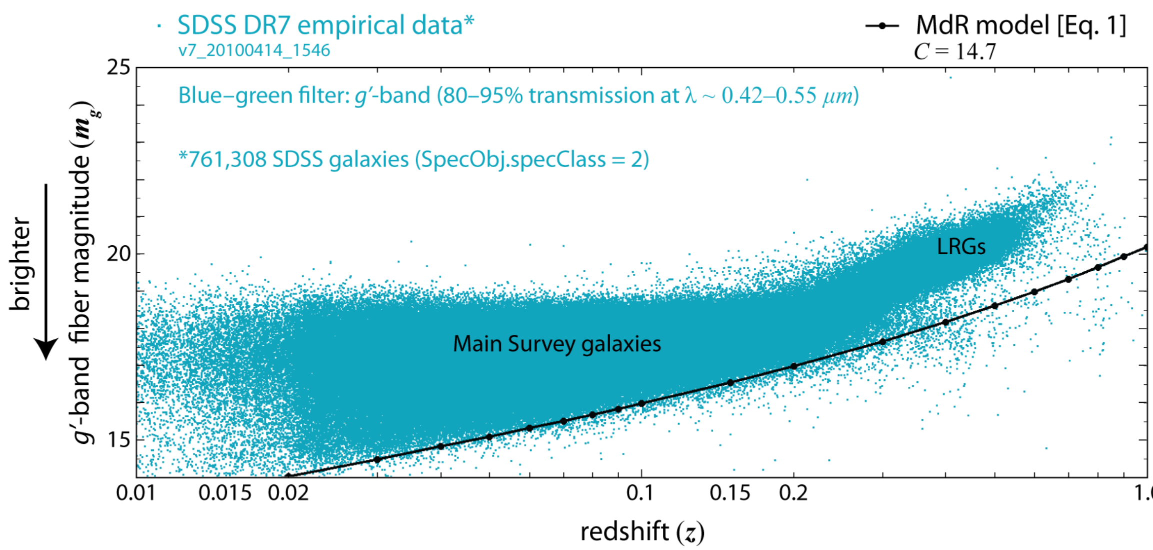

Fig. S3. SDSS g'-band (blue-green light) data compared to MdR model curve. Local dust surrounding the LRGs has a greater extinction effect on light of this shorter wavelength than for the r'-band. As expected according to basic theory, progression of the extinction effect with decreasing wavelength beginning with the infrared z'-band data is evident. Comparative analysis of the data provides empirical measurement of the relative abundance and size of dust grains surrounding dusty (i.e., red) galaxies.